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Harding Lawson Associates

FINAL
Phase I Treatability Study Work Plan
Perchlorate in Groundwater
Baldwin Park Operable Unit
San Gabriel Basin

Engineering and Environmental Services

HLA

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Phase I Treatability Study Work Plan Perchlorate in Groundwater Baldwin Park Operable Unit San Gabriel Basin

Prepared for

Baldwin Park Operable Unit Steering Committee

HLA Project No. 37933 003

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October 6, 1997

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1.0 INTRODUCTION

For the past several years the Baldwin Park Operable Unit Steering Committee (BPOUSC), the U.S. EPA Region IX (U.S. EPA), Three Valleys Municipal Water District (TVMWD), and the Metropolitan Water District of Southern California (MWD) have been planning a combined groundwater remediation and water supply project in the San Gabriel Basin, California. Project planning was initiated in response to a requirement of U.S. EPA to remediate a plume of volatile organic compounds (VOCs) in groundwater in the Cities of Azusa and Baldwin Park. This plume is distributed from locations north of Interstate 210 in the City of Azusa southwest to locations in the vicinity of Interstate 10 in the City of Baldwin Park. This area is called the Baldwin Park Operable Unit (BPOU).

The BPOUSC was in the process of negotiating agreements for the project with the U.S. EPA, MWD, and TVMWD when in June 1997 concentrations of perchlorate ion, above the State of California Department of Health Services (DHS) provisional action level of 18 $\mu g/L$, were found in BPOU groundwater. Before the project can move forward, the potential impact that perchlorate has on the conceptual project design must be evaluated. Perchlorate in BPOU groundwater is particularly troublesome since there is no treatment technology that has been demonstrated to be effective in reducing concentrations of perchlorate to the provisional action level.

Treatability testing at a pilot-scale has been successfully performed at the Aerojet General Corporation (Aerojet) facility near Sacramento, California. The technology can be described as a biochemical reduction process using a fixed film bioreactor. The fixed film is attached to granular activated carbon operated as a fluidized bed (GAC/FB). This pilot-scale test demonstrated that the technology was effective in treating perchlorate in groundwater; however, there were several important differences. First, the flow rate was 0.1% of that needed in San Gabriel Basin. Second, the influent perchlorate concentration was over 100 times that expected in San Gabriel Basin. Finally, the pilot system was not designed to achieve nor did it achieve effluent perchlorate concentrations less than the 18 $\mu g/L$ provisional action level.

The purpose of this Work Plan is to describe the approach and methods that will be used in performing pilot-scale treatability testing of the GAC/FB biochemical reduction technology specifically for application in San Gabriel Basin. The pilot-scale testing will be performed in two phases. In the first phase the objective is to assess if the chosen technology can achieve the target effluent goal. In the second phase, scientific and engineering data needed to design and construct a full-scale treatment system will be collected.

Although this GAC/FB treatment technology has shown the potential to treat perchlorate at concentrations present in San Gabriel groundwater, other treatment technologies may also be applicable. The BPOUSC is in the process of completing a technology screening to assess the viability of other treatment technologies and make recommendations regarding bench-scale and pilot-scale testing if appropriate.

2.0 HISTORY OF PERCHLORATE ISSUES

In February 1997 perchlorate was discovered in five drinking water supply wells in Sacramento, California. This discovery was a result of the recent improvement in the method of perchlorate analysis which has only allowed detection of perchlorate in water at concentrations below the level which EPA and DHS considers acceptable for use by the public (18 $\mu g/L$) since early 1997. The detection of perchlorate in Sacramento water supply wells led DHS to perform sampling and analysis of groundwater for perchlorate in other portions of the state including San Gabriel Basin.

2.1 Distribution of Perchlorate in the BPOU

Perchlorate was first detected in San Gabriel Basin groundwater in June 1997 by DHS. This prompted the Main San Gabriel Basin Watermaster (MSGBWM) and the BPOUSC to perform additional groundwater sampling and analysis to better understand the distribution of perchlorate in groundwater.

To date, the BPOUSC has compiled perchlorate data for over 50 monitoring wells, production wells, and sampling points in the vicinity of the BPOU. Perchlorate analysis for production wells was performed on samples obtained by the DHS and MSGBWM and provided by the San Gabriel Basin Water Quality Authority (SGBWQA). Groundwater samples from monitoring wells in the BPOU were collected by Camp Dresser McKee, Harding Lawson Associates, and Geosyntec on behalf of the BPOUSC.

The lateral and vertical distribution of perchlorate in groundwater has been previously described (see "The Distribution and Treatability of Perchlorate in Groundwater, Baldwin Park Operable Unit, San Gabriel Basin" [HLA, 1997a], "Final Addendum to Sampling and Analysis Plan, Pre-remedial Design Groundwater Monitoring Program, Baldwin Park Operable Unit, San Gabriel Basin" [HLA, 1997b]). In general, the area which contains concentrations greater than the DHS provisional action level of 18 $\mu g/L$ is 5 to 6 miles in length, oriented from northeast to southwest, approximately 1 mile in width, and up to 800 feet in depth. This approximate perchlorate distribution is based on maximum concentrations detected in any sample or at any depth within a given well.

It should be noted that for the majority of these wells, only a single sample has been collected. In addition, there is uncertainty regarding the concentrations above the 18 $\mu g/L$ provisional action level in both the northernmost and southernmost portions of the plume. Therefore, the known distribution may change as wells are resampled or new wells constructed and sampled.

2.2 Toxicity/Provisional Action Level

A significant source of uncertainty associated with the potential effect that concentrations of perchlorate ion in groundwater may have on the selection of a remedy for the BPOU is the limited data available on the toxicity of low concentrations of perchlorate to humans. Limited animal studies have been performed and no studies documenting human effects at low concentrations are available. Therefore, the provisional Reference Dose (RfD) and provisional action level established by DHS have an inherently high level of uncertainty. These may be subject to significant change once appropriate studies have been conducted.

The primary human health concern related to perchlorate is that it interferes with the thyroid gland's ability to utilize iodine to produce thyroid hormones. While high doses of perchlorate (mg/kg per day levels) have been used therapeutically in medicine, no studies have examined the health effects at the lower dosages potentially received from the ingestion of groundwater at concentrations present in the San Gabriel Basin groundwater. Examples of therapeutic perchlorate use are as a medicine to treat Grave's disease, a condition in which excessive amounts of thyroid hormone are produced, and in Europe to counteract the side effects of the heart drug amiodarone.

In December of 1992, the U.S. EPA National Center for Environmental Assessment (NCEA) responded to a request by U.S. EPA Region IX to evaluate the toxicity of perchlorate in soil and groundwater. Based on limited data on the toxicity of this ion, NCEA recommended a provisional RfD for soil and groundwater that included a conservative safety factor and correlated with acceptable levels of 70 mg/L and 3.5 $\mu g/L$, for these media, respectively. NCEA later stated in a letter dated February 25, 1997, that these provisional RfDs were merely opinions provided to EPA regional officials and were not to be considered formal EPA policy.

In April of 1993, the Perchlorate Study Group (PSG) was formed by the U.S. Air Force, various aerospace companies, and the two primary manufacturers of perchlorate compounds. The mission of the PSG was to review and evaluate information on the toxicity of perchlorate and develop better information on what constitutes an acceptable level of perchlorate in soil and groundwater.

In June 1995, the PSG submitted a position paper to the U.S. EPA presenting the groups' findings. The U.S. EPA again reviewed available toxicological data on perchlorate and concluded that although information was available on the effects of high concentrations of perchlorate on the thyroid, there was not enough information on the effects of long-term exposure to low concentrations. In October 1995, the U.S. EPA responded to the PSG paper by recommending a provisional reference dose correlating to an acceptable level in groundwater that ranged between 3.5 and 17.5 $\mu g/L$. Because there was limited information available, the U.S. EPA recommendation includes a large margin of safety. In fact a 300-fold margin of safety above the level at which no health effects were observed was used to establish the 17.5 $\mu g/L$ provisional standard. This value became the 18 $\mu g/L$ value currently used as the DHS provisional action level.

In March 1997, the PSG assembled a technical Peer Review Panel of nationally recognized scientists to evaluate the health effect of perchlorate in drinking water. The conclusion of this panel was that there are insufficient toxicological data available to establish a technically defensible RfD or support the U.S. EPA provisional RfD.

In May 1997, the Air Force and the PSG brought the Peer Review Panel back together with California state and federal regulators in Cincinnati, Ohio. The purpose was to have the panel develop a protocol and the scope of studies that would lead to a recommendation to U.S. EPA for a new RfD which could serve as the basis for a groundwater MCL. The Air Force and the PSG have undertaken to commence the necessary studies in August 1997, interpret the data, peer-review the results, and submit recommendations to U.S. EPA by July 1998.

It should be noted that to date the U.S. EPA has not endorsed the Peer Review Panel but did have representatives participate on the panel. Further, U.S. EPA has not endorsed the evaluation process or committed to a schedule for review of the resultant recommendations or its effect on the U.S. EPA's former provisional RfD. As a result it is uncertain how long it will take for the provisional RfD to be revised and an MCL established.

In February 1997 the DHS set a provisional action level for perchlorate in groundwater at 4 $\mu g/L$, but at that time laboratory methods were not designed or approved to measure concentrations this low. In May of 1997 DHS, based on the results of U.S. EPA's recommendations, revised its provisional action level from 4 $\mu g/L$ to 18 $\mu g/L$. DHS stated that it had reevaluated scientific studies in greater detail and had determined that 18 $\mu g/L$ is consistent with the range of perchlorate exposures the U.S. EPA considers protective of human health. DHS requires that water suppliers promptly notify customers whenever perchlorate is present in concentrations greater than 18 $\mu g/L$.

2.3 Analytical Methodology and Detection Limits

At the time that the U.S. EPA set its provisional RfD and the DHS set its provisional action level for perchlorate in groundwater, no EPA laboratory method existed and few laboratories were set up to analyze for perchlorate. Some laboratories were using a modification of EPA Method 300 (Ion Chromatography), while others were using an Ion Selective Electrode (ISE). Reporting limits for analysis of perchlorate in water were generally in the range of 400 to 1,000 $\mu g/L$.

It was not until April 1997, that the DHS attained the current reporting limit of 4 $\mu g/L$ after having performed its own method development (Sanitation and Radiation Laboratories Branch). To date, this method has not be peer reviewed. Because perchlorate is not a regulated substance DHS does not issue laboratory certification for method analysis. DHS will however issue informal approval to perform perchlorate analysis once a laboratory meets DHS requirements.

To receive DHS approval the laboratory must hold a current certification for EPA Method 300, develop a Standard Operating Procedure (SOP), determine its Method Detection Limit (MDL), and prepare a data package demonstrating its ability to perform the analysis. The laboratory must then contact the DHS who will send out a field auditor. The laboratory must perform analysis on the samples with acceptable results (±10%) in the presence of the auditor. To date, at least six laboratories in California have received approval.

3.0 PREVIOUS PERCHLORATE TREATABILITY REVIEW

In response to the presence of perchlorate in groundwater at Aerojet's Sacramento facility, a considerable amount of work has been performed to address perchlorate treatability. This work, consisting of technology screening, bench-scale studies, pilot-scale studies, and the design of a full-scale (1,500 gpm) system, was performed by Aerojet and a consultant starting in 1994.

3.1 Literature Review

In 1994, Aerojet completed an initial screening of technologies available for treatment of perchlorate. An on-line data search was first performed. The following databases were searched:

- Energy SciTech (1974-1994)
- Ei Compendex Plus (TM) (1970-1994)
- National Technical Information Service (1964-1994)
- Aerospace Database (1962-1994)
- Chemical Engineering Abstracts (1970-1994)
- Biotechnology Abstracts (1970-1994)
- PTS Aerospace/Defense Markets (1986-1994)
- Pollution Abstracts (1970-1994)
- Analytical Abstracts (1980-1994)

Only limited information on the treatment of water for perchlorate was found, and the available data addressed the treatment of high concentration wastewaters, not low concentrations in groundwater. The technologies for which information was found include both biological and physical/chemical treatment methods.

Biological Methods

Biochemical reduction of oxygen-containing compounds, like perchlorate, with the simultaneous biochemical oxidation of organic matter contained in sludge from municipal wastewater treatment plants was the subject of three patents with dates from 1973 to 1994. The patents varied in bioreactor configuration and the source and type of the microorganisms used. Concentrations in wastewater in excess of 7,000 mg/L were the subject of treatment.

A 1973 patent (Yakevlev et al., 1973) describes biochemical oxidation of activated sludge in an unaerated tank. A 1976 patent (Korenkov et al., 1976) is a modification of this approach but a specific microorganism is identified. The source of the microorganism is settled municipal sewage. A 1994 patent (Attaway et al., 1994) held by the U.S. Air Force uses an anaerobic bioreactor and a specific microorganism. Brewer's yeast, cottonseed protein, and whey powder were all added to the bioreactor.

Physical/Chemical Methods

The physical/chemical processes which were reviewed by Aerojet in 1994 included ion exchange, reverse osmosis, an electrochemical process which reduces inorganic oxyhalides, and a process where perchlorate wastewater was treated with an oxidant in supercritical (high temperature, high pressure) water.

The electrochemical method, patented in 1992 (Kaczur et al., 1992), uses an anode and cathode separated by a cation exchange membrane. A 1993 paper (Harradine et al., 1993) describes treatment of perchlorate in wastewater with an oxidant (O_2, air, H_2O_2) under conditions of high pressure (200 atm) and temperature (370°C).

In addition to these two techniques, Aerojet's staff reviewed the applicability of ion exchange and reverse osmosis treatment technologies. Although both ion exchange and reverse osmosis are considered technically proven methods for reducing concentrations of dissolved solids in waters, there are significant technical challenges presented by both methods for treatment of water containing perchlorate.

With respect to ion exchange, common groundwater ions will interfere with perchlorate adsorption. The ion exchange resin is regenerated with brine (usually sodium chloride). Perchlorate concentrations in regeneration brine present a unique disposal or treatment problem.

There are significant operational difficulties associated with the use of reverse osmosis. Like ion exchange, perchlorate is not treated but merely conveyed to a waste concentrate that would be a waste disposal challenge. The resultant brine would contain perchlorate and would be significant in volume. In addition, pretreatment of influent, use of anti-fouling chemicals, and membrane cleaning are time-consuming and costly.

Based on the literature review described above, Aerojet decided to pursue laboratory-scale testing of chemical reduction and biochemical methods.

The BPOUSC is in the process of completing an updated technology screening, building upon past work performed by Aerojet. This effort will include a literature review, a review of recent patents and technical articles, and a review of additional technical performance data which may have been generated by various parties interested in perchlorate treatability but not present in the literature.

3.2 Bench-Scale Laboratory Testing

Bench-scale treatability studies for several biochemical and chemical reduction treatment methods were performed by an Aerojet consultant in 1995. The tested water came from Aerojet's Sacramento facility and contained between 7,000 and 8,000 μg/L perchlorate.

Relatively high dosages of several reducing agents (sodium sulfite, sodium bisulfite, and sodium thiosulfate) up to 1,000 mg/L were added under ambient conditions to water containing 7,000 μg/L perchlorate. As perchlorate concentrations did not significantly decrease over time, these reducing agents were concluded to be ineffective, and the process was not taken to pilot-scale.

In addition to chemical reduction, Aerojet staff evaluated the use of ion exchange technology in more detail. Time was devoted to resin selection, resin regeneration, and treatment of regeneration wastes. Efforts were also made to develop a method for biodegradation of perchlorate in these wastes.

Two biochemical reduction methods were tested on a bench-scale: a fixed film bioreactor using submerged plastic media, and a fluidized bed bioreactor using a granular activated carbon media (GAC/FB). For both processes the water to be treated was amended with an organic carbon source (acetate or alcohol) and nutrients (nitrogen and phosphorus) before entering the bioreactor.

Both biochemical reduction methods were shown to be effective in reducing perchlorate concentrations. The GAC/FB system was more resilient, recovering more quickly from system upsets such as feed water variations. The GAC/FB system also accommodated a higher (6-fold) perchlorate loading rate of 0.70 grams perchlorate/liter/day in comparison to the submerged plastic media loading rate of 0.11 grams perchlorate/liter/day. Effluents for both processes were below the 400 μg/L reporting limit for perchlorate.

Because of the success with the biochemical treatment methods, and due to the comparatively better performance of the GAC/FB method, this method was taken to pilot-scale.

3.3 Pilot-Scale Testing

In 1996, a 30 gpm skid-mounted pilot system, was set up at the Aerojet facility in Sacramento. The pilot-scale system operated between April and December of 1996. Operation of this pilot-scale system allowed optimization of feed rates for the organic carbon source (alcohol) and nutrients (nitrogen in the form of urea and phosphorus in the form of ammonium phosphate). Alcohol was added in molar ratio to perchlorate of approximately 4:1. Nitrogen and phosphorus levels were augmented to be similar to those described in the literature to assure microbial growth.

Effluent concentrations were consistently less than the 400 μg/L laboratory reporting limit for perchlorate. Effluent concentrations were 500 μg/L for phosphorus, 340 μg/L for ammonia-nitrogen, and less than 50 μg/L for nitrate-nitrogen.

The initial pilot-scale effluent contained very low or non-detectable levels of bacteria. After one month of operation, bacteria were at non-detectable levels.

3.4 Full-Scale Design

Aerojet is in the process of designing a full-scale perchlorate treatment system for one of the groundwater extraction and treatment systems at their Sacramento facility. The design and construction are currently scheduled to be complete in the fall of 1998. The hydraulic loading rate for the system is 1,500 gpm. The full-scale system will be similar to that pilot-tested in 1996.

Aerojet is working with the design contractor to optimize certain design features which will result in lower effluent concentrations. The pilot-scale study was completed prior to the recent reduction in laboratory reporting limits by agency and commercial laboratories and, therefore, Aerojet and its contractor are hoping to modify either the design or operating parameters to produce effluent below the 18 μg/L provisional action level.

In addition, Aerojet and its contractor have located an alternative source of microorganisms. Waste sludge from the food processing industry was determined to contain acceptable microorganisms.

3.5 Biological Treatment Technology Overview

Biological treatment, or biochemical reduction of perchlorate, involves a microbially induced reaction in which perchlorate is biochemically reduced to form chloride, oxygen, and biomass, simultaneous with the biochemical oxidation of an organic substrate. The substrate is typically selected based on its readily biodegradable chemical structure, non-hazardous nature from an environmental standpoint, relatively low cost, and availability.

Biological treatment technologies generally fall into two classes: suspended-growth and attached-growth (fixed-film). Attached-growth systems are expected to be better suited to the relatively low influent perchlorate concentrations and are therefore the focus of BPOUSC efforts. Attached-growth systems can typically attain higher concentrations of microorganisms per unit reactor volume, and because the microorganisms are attached to media within the biological reactor, there is no requirement for return of microorganisms to the treatment reactor.

The GAC/FB technology is an attached growth (fixed film) process which utilizes granular activated carbon as a support medium for biological attachment and growth in a fluidized bed reactor. The GAC/FB technology offers the additional advantage of greater surface area on which microorganisms can attach and grow, as well as the presence of activated carbon, which provides some buffer capacity to varying operating conditions. Groundwater, amended with an organic substrate (e.g., alcohol, acetate) and nutrients (nitrogen and phosphorus), is introduced into the treatment bed. As groundwater passes through the system, the microorganisms derive energy from the oxidation of the organic substrate, simultaneously bioreducing the perchlorate. Thus, the microorganisms multiply to a steady-state level, determined by the organic loading to the system.

Non-viable microorganisms eventually become detached from the media, and exit the system in the groundwater effluent, allowing new microorganisms to attach and reproduce. The reaction takes place under anoxic conditions, and therefore no air or oxygen (other than that contained in the influent water) is introduced to the system.

4.0 DATA REQUIREMENTS

The long-term goals of this treatability work are: 1) to demonstrate the technology can achieve effluent goals for perchlorate and nitrate concentrations, and 2) to collect the data necessary for the design and construction of a full-scale treatment unit that will be part of the BPOU treatment train, delivering potable water to local and regional water purveyors.

The objectives of this Phase 1 treatability study are to evaluate the performance of the GAC/FB treatment technology previously tested at Aerojet's Sacramento facility with the following modifications:

- Decrease the concentration of perchlorate in the influent to a concentration representative of that which will be present in San Gabriel Basin groundwater
- Increase the concentration of nitrate in the influent water to a concentration representative of San Gabriel Basin groundwater
- Achieve a lower perchlorate concentration in treatment plant effluent
- Test the effectiveness of an alternative source of microorganisms.

Phase 1 testing is planned at Aerojet's Sacramento facility because many of the pilot system components are onsite, staff familiar with prior pilot system construction and operation are available, and there are no complicating issues related to the discharge of treated water.

4.1 Demonstrate Technology Can Achieve 18 μg/L Limit or Lower

At the time the pilot-scale study was performed at Aerojet's Sacramento facility, the goal was to produce effluent that was less than the 400 μg/L laboratory reporting limit current at that time. When the pilot-scale study was completed, the effluent generally was characterized by perchlorate concentrations less than 100 μg/L. Measurement of concentrations at this level had a higher level of uncertainty as they were below the established reporting limit. At that time it was not possible to measure to the current reporting limit of 4 μg/L. Therefore, it was not possible to optimize system flow rate, organic carbon source, or nutrients to see if lower effluent concentrations were possible. Therefore, it is uncertain if the full-scale system to be constructed by Aerojet in Sacramento may reach treatment goals for the BPOU. Treatability studies will need to demonstrate that a sufficiently low perchlorate concentration in treatment plant effluent is possible.

4.2 Evaluate Lower Perchlorate Influent Concentration

Based on the distribution of perchlorate in San Gabriel Basin groundwater, the configuration of extraction wells and flow rates described in the December 1996 Pre-Remedial Design Report (CDM, 1996), and modifications to the extraction plan discussed with U.S. EPA, the BPOU extraction system, as conceived, would produce groundwater containing concentrations of perchlorate between 50 and 100 μg/L. This value was estimated by selecting surrogate wells for each extraction well location, assigning recently measured concentrations from each surrogate well to its corresponding extraction well, and flow-weighting these concentrations based on expected pumping rates to produce a flow-weighted average concentration for the BPOU extraction system. This method is a rough estimation of concentrations that will be initially extracted. The actual concentrations present in the extracted groundwater will be known after extraction wells are constructed and pumped at their designed flow rate.

Although concentrations of perchlorate in groundwater at Aerojet's Sacramento facility that were used as influent to the pilot test ranged from 7,000 to 8,000 mg/L, there are wells at the Sacramento facility that have lower perchlorate concentrations. This treatability test will extract water from wells containing perchlorate concentrations representative of that anticipated in San Gabriel Basin. A well has been selected (40-11) that is currently part of one of Aerojet's groundwater extraction and treatment systems (GET-B). This well consistently produces water containing approximately 50 ug/L perchlorate and 50 to 70 mg/L nitrate.

4.3 Utilize Higher Nitrate Influent Concentration

Influent groundwater during the pilot testing at Aerojet's Sacramento facility was characterized by low (1.5 mg/L) nitrate concentrations. However, the results of the pilot-scale study performed in Sacramento show effluent nitrate concentrations less than 0.05 mg/L. This suggests that along with consumption of alcohol and reduction of perchlorate, that reduction of nitrate is also occurring in the fixed film bioreactor.

Supporting evidence that the same anoxic conditions that contribute to the reduction of perchlorate may also reduce nitrate concentrations may be found in the literature where processes using bacterial denitrification of wastewater have been described. Although denitrification has not been widely applied to drinking water systems do exist in Colorado, Texas, and France. One such system was designed for the town of Wiggins, Colorado to denitrify their drinking water. The process equipment, designed and testing performed by Joann Silverstein of the University of Colorado, Boulder (Silverstein, 1997). The system consists of a packed tower fixed film bioreactor where denitrifying bacteria are supported on a high-porosity plastic media.

This observation could have a significant beneficial effect on the BPOU project as influent nitrate concentrations have been estimated between 20 and 25 mg/L, by the same method described above to estimate influent perchlorate concentrations. Although these concentrations are well below the 45 mg/L MCL, they are substantially higher than concentrations currently received by customers of MWD and TVMWD. Should the GAC/FB biochemical system prove to be an effective method of reducing nitrate concentrations in treatment plant effluent, it may be possible to reduce both perchlorate and nitrate concentrations.

Preliminary evaluation of candidate wells identified a well (40-11) at Aerojet's Sacramento facility that has historically produced water containing between 50 and 70 mg/L nitrate. In addition this well is part of a current groundwater extraction system so that water quality is anticipated to remain relatively constant for the duration of the pilot test.

4.4 Evaluate Different Source of Microorganisms

The source of microorganisms in the previous study was municipal wastewater treatment plant sludge. This presents a concern of introducing pathogens into potable water supplies. Pilot-scale work has demonstrated that pathogens are not present in pilot plant effluent; however, these pathogens remain a concern.

The Phase 1 treatability study will utilize waste sludge from the food processing industry. The waste sludge will likely contain microorganisms appropriate for perchlorate reduction, but lack the pathogens that may be of concern.

4.5 Phase 2 Pilot-Scale Treatability Study

Assuming Phase 1 results demonstrate effluent goals can be met, Phase 2 testing would be performed. It is the intention of the BPOUSC to perform Phase 2 treatability testing at a site in the San Gabriel Basin. Details and logistics regarding this testing will be developed during the performance of Phase 1 testing. Details which will be resolved during Phase 1 testing will include the well site where treatability testing will be performed, the flow rate at which the testing will be performed, and the method and condition under which the effluent will be delivered.

Phase 2 testing could commence in early 1998, with testing complete and a draft report available for EPA review later in 1998. About this time Aerojet's Sacramento perchlorate treatment unit will have come on-line and several months of performance data should be available. Input from both phases of treatability testing and performance data from Aerojet's Sacramento treatment unit would allow the BPOUSC to proceed with design of the BPOU project.

The Phase 2 treatability testing objectives are: 1) determine the efficiency of perchlorate reduction, 2) evaluate required nutrients, 3) assess factors affecting biomass stability, 4) assess the effect of various nitrate concentrations, 5) evaluate relative bacterial preference for perchlorate and nitrate and the role that competing electron acceptors play in system performance and 6) establish filtration/disinfection requirements for potable water use.

5.0 TREATMENT EQUIPMENT DESCRIPTION

The central reactor for the GAC/FB pilot system will be leased from a contractor. Additional components for the pilot system are available at Aerojet's Sacramento facility. The pilot system, rated for a once through flow rate of 30 gpm (113.6 liters/minute), is skid mounted. The system includes a bioreactor with granular activated carbon, fluidization pump, nutrient feed system, and biological growth control system.

A schematic of a generalized GAC/FB bioreactor is presented as Figure 5-1. A generalized process and instrumentation diagram is presented as Figure 5-2. These diagrams are not specific to the Phase 1 Pilot-scale test. The exact configuration of the treatability testing equipment will differ from these diagrams to suit treatability test objectives.

An idealized mass flow diagram is presented in Figure 5-3. To simulate the current BPOU treatment system, VOCs will first be removed with the use of a portable air stripper. VOC-free groundwater will then flow into the GAC/FB unit. Sample ports will be provided before and after the air stripper.

The GAC/FB pilot unit is enclosed in a weather resistant container for protection from freezing during cold weather operation. If necessary, the reactor column, and all associated piping located outside of the container, will be insulated and wrapped with heat tape.

An alcohol metering line, constructed of stainless steel tubing, will enter the GAC/FB pilot unit influent line just prior to the influent sample port. The alcohol will be added to the influent to provide a readily-degradable carbon source for the microorganisms. The alcohol will be purchased in 55-gallon drums. Because the alcohol is flammable, the drums will be stored in a fire-rated outdoor storage cabinet which contains an integral sump for spill control. The alcohol will be metered from the 55-gallon drum using a hazardous duty diaphragm metering pump which is UL-listed for use in Class I, Group D, Division I hazardous locations. Containment around the metering pump will be provided for spill control. The flow rate of the alcohol will be measured with a graduated cylinder and stopwatch.

Sample ports will be provided immediately before and after the GAC/FB system. A sample collection system will be installed in the reactor so that samples can be collected from the 25, 50, and 75 percent points in the reactor. After the effluent exits the GAC/FB system, it will flow by gravity to a 500-gallon, polyethylene equalization tank equipped with level controls. From the equalization tank, the effluent will be discharged directly to the GET-B Treatment Pond. From the equalization tank water can be directed back to the GAC/FB system for further treatment if necessary.

The equalization tank pump will be a centrifugal end-suction pump. Operation of the effluent equalization tank pump will be controlled by high-high, high, and low-level switches in the equalization tank. When the high-high level switch is activated a signal will be sent to the solenoid valve to close the influent line. The closed valve will eliminate flow to the GAC/FB unit to prevent spills from the system. In addition, the high-high level switch will act as a fail-safe shutdown and signal the alcohol metering pump to turn off so that it no longer supplies alcohol to the influent line. When the high-level switch activates, the equalization tank centrifugal pump will be sent a signal to turn on, discharging the contents of the tank to the GET-B Treatment Pond. When the low-level switch activates, the equalization tank pump will be signaled to turn off. A totalizer will be installed to measure the total water flow treated by the system.

Filtration of the treatment system effluent will not be necessary before discharge. Pilot-scale testing of filtration equipment may be necessary prior to full-scale system design, but this testing if needed will be performed as part of the Phase 2 Treatability Study.

6.0 PILOT SYSTEM OPERATION AND MAINTENANCE PLAN

6.1 System Start Up and Operation

Upon delivery of the GAC/FB bioreactor to the site, a general/mechanical contractor will perform the mechanical and electrical installation. During system construction, personnel from HLA and Aerojet will provide oversight. The system will be filled with clean water and hydraulically operated prior to adding carbon or microbial seed to the GAC/FB system to insure proper, leak-free operation.

After leak and mechanical testing, the system will be drained and the GAC/FB reactor column will be filled with the recommended amount of granular activated carbon. The remaining free volume of the GAC/FB system will then be filled with process water and the microbial seed. The GAC/FB system will be operated in recycle mode for a short period of time to allow for growth and attachment of the microorganisms to the GAC. During recycle mode, no influent groundwater will be introduced to the system. The nutrient feed system will be started during the recycle period and batch additions of alcohol, perchlorate, and nutrients will be added on a regular basis to support the microbial growth.

After sufficient time is allowed for microorganism attachment (approximately one week), groundwater impacted with perchlorate will be introduced to the GAC/FB system. At this time, the alcohol feed system will be started. Samples of the GAC/FB system effluent will be collected and analyzed for perchlorate, alcohols, and other conventional parameters. Effluent will be discharged to the GET-B Treatment Pond.

The flow rate of air stripper effluent and the dosage of alcohol will be adjusted during the startup period to establish a stable microbial population in the GAC/FB system. Nutrients will be dosed at a rate sufficient to satisfy microbial requirements. After the removal of perchlorate is established at the initial conditions, the alcohol and hydraulic loading rates will be varied in a controlled, step-like manner until the target organic loading rate is established while achieving perchlorate removal.

Initial and target loading rates were developed based on previous work, and considering influent water quality from the well selected for treatability testing. The initial organic loading rate is expected to be approximately 2.4 grams of chemical oxygen demand (COD) per liter volume of fluidized carbon in the reactor per day (grams COD/liter/day) [150 pounds COD/1,000 ft^3 of fluidized carbon/day]. The target organic loading rate will be 4.8 grams COD/liter/day [300 pounds COD/1,000 ft^3 of fluidized carbon/day]. Additions to the COD loading in the system will be made solely by the addition of alcohol.

Once the target organic loading rate has been established, the system operating conditions will be optimized. After initial stable operation is achieved, ports at the 25, 50, and 75 percent points of the GAC/FB system will be sampled to assess the interim concentration profile across the reactor. This information will be used to make controlled, step-like adjustments to the alcohol and hydraulic loading rates to minimize the amount of alcohol introduced to the system at the maximum hydraulic flow rate.

Targeted analytical parameters will be measured after each change in operating conditions. Although it is anticipated that the system will respond rapidly to changes in influent quality, nutrient feed, or alcohol feed, approximately 24 hours will be allowed to pass and daily samples collected before additional changes are made. This will ensure reactor stabilization and allow a better understanding of how changes to reactor operation affect effluent quality.

HLA personnel will assume operation and maintenance responsibilities. Operation and maintenance activities and frequencies will be modified as necessary to ensure proper control and performance of the GAC/FB system. A logbook will be maintained at the site for recording all operating activities and observations. The logbook will serve as a daily checklist to ensure that necessary maintenance, sampling, and observations are conducted.

6.2 Health and Safety Plan

A Site Health and Safety Plan, prepared by HLA, will govern the activities of all HLA workers at the site who are associated with this pilot-scale treatability study. This plan will be prepared and submitted after Work Plan approval but prior to system start up.

6.3 Quality Assurance Project Plan

HLA's Quality Assurance Management Plan (QAMP) assures that appropriate measures will be taken to assure project data quality objectives (DQOs) are achieved and data integrity is maintained. In addition to DQOs, HLA's QAMP addresses methods for sample collection and handling, sample custody, the type and frequency of quality control samples, laboratory quality control procedures, methods for data verification, reduction, management and interpretation, record keeping and corrective actions.

For field activities approximately five percent of all samples will be collected as splits. Field blanks, equipment blanks, and trip blanks will be submitted to the project laboratory on a daily basis when daily samples are collected and on a weekly basis when weekly samples are collected. All samples will be appropriately labeled, packaged, and will be shipped to the project laboratory under chain of custody.

Analysis of samples by the project laboratory will be performed in conformance with laboratory QC procedures and QC procedures specified by each of the certified or approved analytical methods. Table 6-1 details laboratory quality control procedures and statistical analysis guidelines.

7.0 SAMPLING AND ANALYSIS PLAN

The Phase 1 treatability study will be divided into two phases: a system startup monitoring period and a performance monitoring period. In the system startup period, sampling during the first week will be minimal as the microorganism population grows and stabilizes. During the second week of the startup period, sampling will be frequent to provide complete characterization of the process influent and effluent and allow adjustments to operating conditions. After steady-state operating conditions are reached, less frequent but regular performance monitoring will be conducted to monitor treatment process performance. The sampling and analytical schedules for the two periods of operation are presented in Tables 7.1 and 7.2, respectively. These tables illustrate the location and frequency of sample collection as well as the compounds to be analyzed.

7.1 Field Data Collection

During the first week of system startup, only minimal monitoring will be performed to assure steady-state conditions while microorganism populations are increasing and stabilizing. The parameters to be measured in the field at the pilot plant include flow rates, dissolved oxygen (DO), pH, oxidation-reduction potential (ORP), and temperature. Flow rates will be continuously monitored with in-line, correlated flow meters. Flow meter readings will be confirmed by monitoring the effluent volume that accumulates in the polyethylene tank. A reference line for tank volume versus fluid height is present on the outside of the tank. The flow from the alcohol metering pump will be measured using a graduated cylinder and a stopwatch.

The DO concentrations in the influent and effluent of the GAC/FB system will be monitored daily with a field DO meter and field probe or equivalent in-line device. Each day the DO meter will be calibrated using the air calibration method. DO measurements will be corrected for temperature and pressure.

A hand held pH meter or equivalent device will used to measure pH daily; pH will be recorded daily. The meter will be standardized to two reference buffer solutions each day prior to obtaining pH measurements. A hand held electrode or equivalent device will used to measure ORP; ORP will be recorded daily.

The influent and effluent temperature of the GAC/FB system will be measured daily with a hand held mercury thermometer or equivalent device.

7.2 Sample Collection

Sample tubing located on the GAC/FB influent sample port and the GAC/FB effluent sample port will be constructed of short sections of stainless steel tubing. Valves will be located on the sample port lines to reduce the velocity of the sample as it enters the sample bottles and thereby reduce turbulence. Tubing and valves on sample port lines will be opened and extensively flushed to ensure collection of representative samples.

All GAC/FB influent samples will be collected at the sample port located downstream of the alcohol addition location. GAC/FB effluent samples will be collected at the sample port located immediately following discharge from the GAC/FB system. Samples collected from the pilot system will be in the form of discrete grab samples, except in the case of some of the effluent alcohol samples collected from the polyethylene tank in the early stages of the project which will be composite samples. Grab samples provide better control than composite samples for monitoring the effects that changes in influent quality and reactor operating conditions have on reactor performance.

After collection, VOC samples in zero-headspace vials will be inverted and inspected for the presence of bubbles. All samples will be placed into coolers for same-day transportation to the analytical laboratory. Influent and effluent samples will be stored and transported on ice in separate coolers to preserve the samples and to prevent cross contamination of samples. Upon arrival at the laboratory, the samples will be stored at 4°C in walk-in coolers. Samples collected on Sunday will be stored in a refrigerator onsite, as the laboratory is not open that day. Samples will be delivered to the laboratory as soon as possible on Monday.

Sample container selection and sample preservation techniques will comply with U.S. EPA guidelines detailed in SW-846. Sample tags indicating sample location, date and time of sampling, and the initials of the individual who collected the sample will be attached to each sample. Each sample will be logged onto a chain-of-custody form. Copies of all chain-of-custody forms generated during the pilot study will be kept on file and available for review. Analytical method requirements are detailed in Table 7.3.

7.3 Analytical Testing

The project laboratory will perform analyses for volatile organic compounds (VOCs), ammonia-nitrogen, alkalinity, chloride, phosphate, BOD, COD, total suspended solids, total dissolved solids, turbidity, perchlorate, chlorate, chlorite, hypochlorite, nitrate, nitrite, sulfate, alcohols, metals, and bacteriology. The purpose of this testing is to evaluate the effectiveness and mechanisms of perchlorate reduction. Analytical testing will be conducted using the U.S. EPA approved methods.

8.0 WASTE STREAM MANAGEMENT

Under approval of the Central Valley Regional Water Quality Control Board, system effluent will be discharged directly to the GET-B Treatment Pond. At the conclusion of the study, TCLP testing will be conducted to verify the GAC does not exhibit the hazardous characteristics. After reviewing test results, the GAC will be disposed of in accordance with applicable laws and regulations.

9.0 IMPLEMENTATION TEAM AND COMMUNICATION PLAN

9.1 Implementation Team

Activities described here will be implemented by the team shown on Figure 9-1. Individuals responsible for the implementation of the activities in this Work Plan are: 1) appropriately qualified and licensed, 2) have considerable knowledge of a range of treatment technologies and experience designing and performing bench-scale and pilot-scale treatability tests, and 3) are experienced with the methods and procedures including those related to Health and Safety and Quality Assurance required to perform the proposed work.

This treatability study will be performed by a team of personnel from HLA and Aerojet under the direction of BPOUSC Co-chairpersons, Don Vanderkar and Steve Richtel.

9.2 Communication Plan

Communication during the implementation of this treatability work will be conducted in a manner to facilitate timely decision making and communication of work progress. Lines of communication are shown on Figure 9-1.

John Catts will serve as technical director for the work and be responsible for communicating work progress to the BPOUSC and U.S. EPA.

It is anticipated that work progress and results will be communicated via telephone conversations, meetings, written correspondence, and reports as described in Section 10.0.

10.0 SCHEDULE

This Work Plan was prepared within the schedule proposed by the BPOUSC in the document entitled "The Distribution and Treatability of Perchlorate in Groundwater, Baldwin Park Operable Unit, San Gabriel Basin" dated July 15, 1997 (HLA, 1997a), and issued in draft form on August 26, 1997. Comments from U.S. EPA dated September 12, 1997 have been addressed in this "Final Phase 1 Treatability Study Work Plan".

Planning and preparation for Phase 1 treatability testing commenced in mid September 1997. Assembly of the pilot-scale bioreactor is presently in progress.

The BPOUSC will provide U.S. EPA with progress reports in the form of conference calls approximately 30 and 60 days following approval of this Work Plan. Assuming an U.S. EPA Work Plan approval date of September 12, 1997, teleconference progress reports will be held in mid-October and mid-November, 1997.

The BPOU will submit to U.S. EPA a written Phase 1 treatability testing progress report within 75 days of Work Plan approval. This progress report will contain preliminary Phase 1 results if available and a schedule for the remainder of the Phase 1 treatability test. In addition this progress report will contain either a Supplemental Work Plan for Phase 2 Treatability Testing or an explanation as to why additional Phase 1 testing is necessary before a Phase 2 Work Plan can be prepared, and a planned submittal date for a Phase 2 Work Plan.

Task Description	Duration from approval	Task Completion Date
Draft Phase 1 Work Plan		8/26/97
EPA, DHS, MWD Review		9/12/97
Phase 1 Mobilization	45 days	10/27/97
Progress Report (telephone)	30 days	10/12/97
Progress Report (telephone)	60 days	11/12/97
Written Progress Report	75 days	11/27/97
Phase 1 Testing	105 days	12/27/97
Draft Phase 1 Report	150 days	2/25/98
EPA, DHS, MWD Review	165 days	3/12/97
Final Phase 1 Report	180 days	3/25/97

11.0 REFERENCES

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CDM, 1996. Draft Baldwin Park Operable Unit, pre-remedial design groundwater monitoring program, pre-remedial design report, December.

Harradine et al., 1993. Oxidation chemistry of energetic materials in supercritical water. *Hazardous Waste and Hazardous Materials* 10, pp. 233-246.

HLA, 1997a. The Distribution and Treatability of Perchlorate in Groundwater, Baldwin Park Operable Unit, San Gabriel Basin, July 15, 1997.

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Kaczur et al., 1992. Process and apparatus for the removal of oxyhalide species from aqueous solutions. U.S. Patent 5,167,777.

Korenkov et al., 1976. Process for purification of industrial waste waters from perchlorates and chlorates. U.S. Patent 3,943,055.

Silverstein, J. and University of Colorado. Biological denitrification of water. Patent awarded 1997.

Yakevlev et al., 1973. Method for biochemical treatment of industrial wastewater. U.S. Patent 3,755,156.

TABLES

Table 6-1
Laboratory Quality Control Procedures

Analytes	U.S. EPA Method	Initial Calibration	Continuing Calibration	Standard	Method Blank		Matrix Spike		Matrix Spike Duplication		Laboratory Control Sample	
					Control Limit	Minimum Frequency	Control Limit (%R)	Minimum Frequency	Control Limit (RFD)	Minimum Frequency	Control Limit (%R)	Minimum Frequency
Volatile Organic Compounds	8260	5 points	Every 10 samples	Every 10 samples and after last sample	Less than MDL	1 per batch	60-140	1 per 20 samples	$\pm$30	1 per 20 samples	60-140	1 per 20 samples
Alcohols	8015	5 points	Every 10 samples	Every 10 samples and after last sample	Less than MDL	1 per batch	50-150	1 per 20 samples	$\pm$30	1 per 20 samples	50-150	1 per 20 samples
Perchlorate	300 (modified)	5 points	Every 10 samples	Every 10 samples and after last sample	Less than MDL	1 per batch	70-130	1 per 20 samples	$\pm$20	1 per 20 samples	85-115	1 per 20 samples
Chlorate, Chlorite, Hypochlorite	300	6 points	Every 10 samples	---	<R.L.	1 per batch	25-125	1 per 20 samples	$\pm$30	1 per 20 samples	50-150	1 per 20 samples
Alkalinity	310.1	6 points	Every 10 samples	---	<R.L.	1 per batch	---	---	---	---	---	---
Chloride	325.2	6 points	Every 10 samples	---	<R.L.	1 per batch	25-125	1 per 20 samples	$\pm$30	1 per 20 samples	60-140	1 per 20 samples
Total Phosphorus	365.2	6 points	Every 10 samples	---	<R.L.	1 per batch	25-125	1 per 20 samples	$\pm$25 or 30	1 per 20 samples	60-140	1 per 20 samples
Nitrogen, Ammonia	350.2	6 points	Every 10 samples	---	<R.L.	1 per batch	25-125	1 per 20 samples	$\pm$25 or 30	1 per 20 samples	70-130	1 per 20 samples
Nitrogen, Nitrate, Nitrite	353.3	6 points	Every 10 samples	---	<R.L.	1 per batch	25-125	1 per 20 samples	$\pm$25 or 30	1 per 20 samples	70-130	1 per 20 samples
Sulfate	375.4	6 points	Every 10 samples	---	<R.L.	1 per batch	25-125	1 per 20 samples	$\pm$25 or 30	1 per 20 samples	70-130	1 per 20 samples

Analytes	U.S. EPA Method	Initial Calibration	Continuing Calibration	Standard	Method Blank		Matrix Spike		Matrix Spike Duplication		Laboratory Control Sample	
					Control Limit	Minimum Frequency	Control Limit (%R)	Minimum Frequency	Control Limit (RFD)	Minimum Frequency	Control Limit (%R)	Minimum Frequency
Title 22 Metals	6000/7000	3 points	Every 10 samples	---	<R.L.	1 per batch	25-125	1 per 20 samples	±25 or 30	1 per 20 samples	50-150	1 per 20 samples
Bacteriology – Coliform/E-Coli	9221B	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Dissolved Solids	160.1	---	---	---	<R.L.	1 per patch	---	---	---	---	---	---
Total Suspended Solids	160.2	---	---	---	<R.L.	1 per batch	---	---	---	---	---	---
Turbidity	180.1	---	---	---	---	---	---	---	---	---	---	---
Biochemical Oxygen Demand	405.1	N/A	N/A	N/A	<0.2	1 per batch	---	---	---	---	---	---
Chemical Oxygen Demand	410.4	6 points	Every 10 samples	Every 10 samples	<R.L.	1 per batch	25-125	1 per 20 samples	±25 or 30	1 per 20 samples	---	1 per 20 samples

N/A = Not Applicable

Table 7.1
Sampling and Analysis Plan
System Startup Monitoring Period (Week 2)

Analytes	GAC/FB Influent	GAC/FB 1/4	GAC/FB 1/2	GAC/FB 3/4	GAC/FB Effluent
Volatile Organic Compounds	2/week				2/week
Alcohols	7/week	7/week	7/week	7/week	7/week
Perchlorate	7/week	7/week	7/week	7/week	7/week
Chlorate, Chlorite, Hypochlorite	1/week	7/week	7/week	7/week	7/week
Alkalinity	2/week				2/week
Chloride	2/week				2/week
Total Phosphorus	7/week				7/week
Nitrogen, Ammonia	7/week	7/week	7/week	7/week	7/week
Nitrogen, Nitrate, Nitrite	1/week	7/week	7/week	7/week	7/week
Sulfate, sulfide	7/week				7/week
Title 22 Metals	1/week				1/week
Bacteriology – Coliform/E-Coli	1/week				7/week
Total Dissolved Solids	2/week				2/week
Total Suspended Solids	2/week				2/week
Turbidity	2/week				2/week
Biochemical Oxygen Demand	7/week	7/week	7/week	7/week	7/week
Chemical Oxygen Demand	7/week	7/week	7/week	7/week	7/week

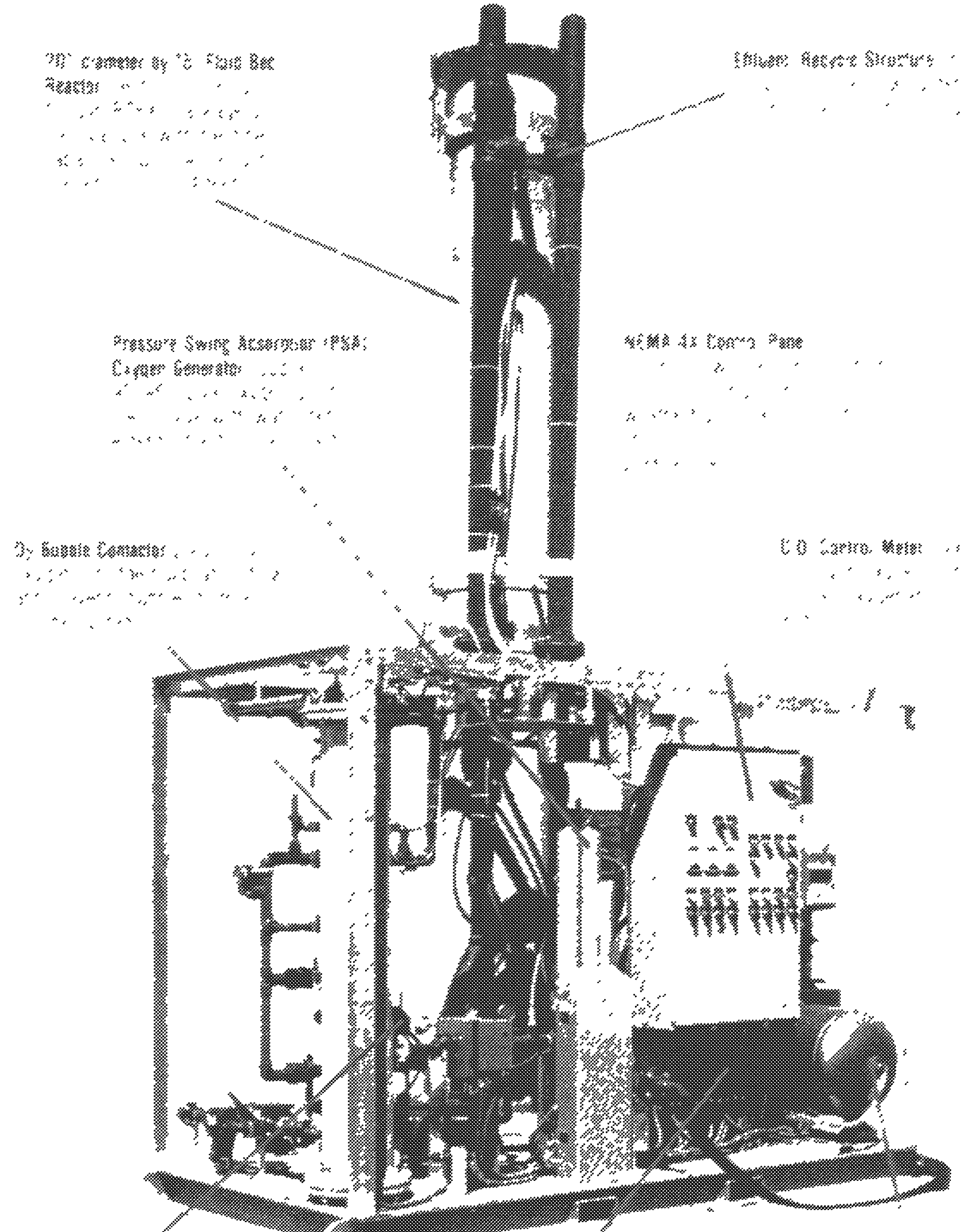
Table 7.2
Sampling and Analysis Plan
Performance Monitoring Period (Weeks 3 through 8)

						Project Total	
Analytes	**GAC/FB Influent**	**GAC/FB 1/4**	**GAC/FB 1/2**	**GAC/FB 3/4**	**GAC/FB Effluent**	**Trip Blanks**	**Duplicates**
Volatile Organic Compounds	1/week				1/week	2	1
Alcohols	7/week	1/week	1/week	1/week	7/week	2	7
Perchlorate	7/week	1/week	1/week	1/week	7/week	7	7
Chlorate, Chlorite, Hypochlorite	1/week				l/week	2	2
Alkalinity	1/week				1/week	2	1
Chloride	1/week				1/week	2	1
Total Phosphorus	1/week				1/week	2	2
Nitrogen, Ammonia	1/week				1/week	2	3
Nitrogen, Nitrate, Nitrite	1/week				1/week	2	2
Sulfate	1/week				1/week	2	2
Title 22 Metals	1/week				1/week	2	1
Bacteriology – Coliform/E-Coli	1/week				7/week	2	3
Total Dissolved Solids	1/week				1/week	2	1
Total Suspended Solids	1/week				1/week	2	1
Turbidity	1/week				1/week	2	1
Biochemical Oxygen Demand	7/week	1/week	1/week	1/week	7/week	2	7
Chemical Oxygen Demand	7/week	1/week	1/week	1/week	7/week	2	7

Table 7.3
Analytical Method Requirements

Analytes	U.S. EPA Method	Preservative	Holding Time	Sample Container	Sample Volume	Method Detection Limit	Reporting Limit
Volatile Organic Compounds	8260	HCL-pH<2	14 days	40 ml VOA	3 x 40 mL	Varied	5 - 100 µg/L
Alcohols	8015	4°C	14 days	40 ml VOA	1 x 40 mL	Varied	100 mg/L
Perchlorate	300 (modified)	Cool 4°C	14 days	Poly	125 mL	28 ppb	4 ppb
Chlorate, Chlorite, Hypochlorite	300	4°C	14 days	Poly	100 mL	Still being determined	200,20,50 ppb
Alkalinity	310.1	4°C	14 days	Poly	500 mL	---	5 mg/L ppm
Chloride	325.2	4°C	28 days	Poly	50 mL	0.72 ppb	1.0 mg/L ppm
Total Phosphorus	365.5	H_2SO_4	28 days	Poly	100 mL	0.04 ppb	0.3 mg/L ppm
Nitrogen, Ammonia	350.1	H_2SO_4	28 days	Poly	100 mL	0.027 ppb	0.1 mg/L ppm
Nitrogen, Nitrate, Nitrite	353.1	4°C	28 days	Poly	100 mL	0.0044 ppb	0.1 mg/L ppm
Sulfate, Sulfide	375.4	Cool 4°C	Sulfate - 28 days Sulfide - 7 days	Poly	100 mL	---	1.0 mg/L ppm
Title 22 Metals	6000/7000	HNO_2 - pH<2	6 months	Poly	500 mL	Varied	Varied
Bacteriology – Coliform/E-Coli	9200	Sodium Thosulfate - 4°C	24 hours	Plastic	100 mL	Varied	Varied
Total Dissolved Solids	160.1	4°C	7 days	Poly	100 mL	---	10 mg/L ppm
Total Suspended Solids	160.2	4°C	7 days	Poly	500 mL	---	5 mg/L ppm
Turbidity	180.1	4°C	2 days	Poly	50 mL	---	INTU
Biochemical Oxygen Demand	405.1	4°C	2 days	1L Amber	1,000 mL	---	3.0 mg/L
Chemical Oxygen Demand	410.4	HNO_2 - pH<2	28 days	Poly	50 mL	8.9 ppb	10 mg/L

FIGURES



REFERENCE: CONTRACTOR EQUIPMENT BROCHURE

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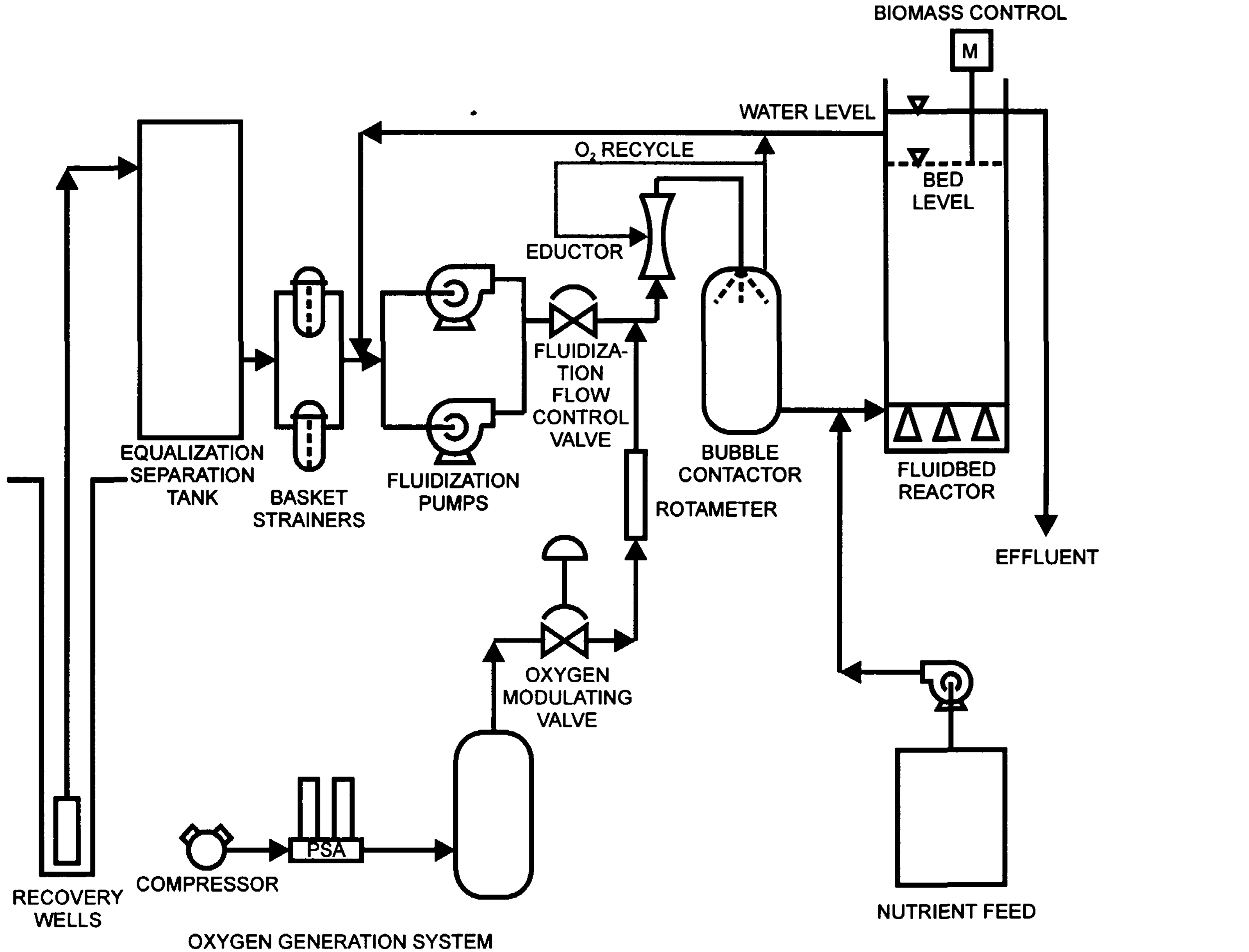
PHOTOGRAPH

5-1



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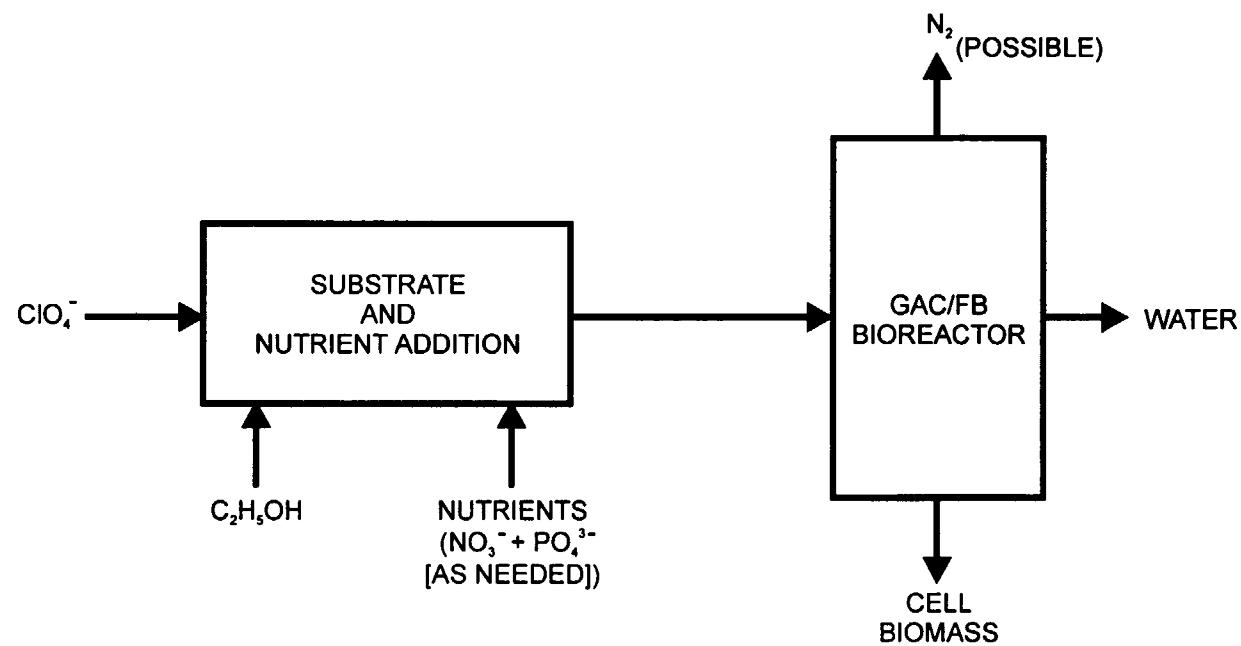
TYPICAL CONTRACTOR PROCESS AND INSTRUMENTATION DIAGRAM

FIGURE **5-2**

DRAWN	PROJECT-TASK NUMBER	APPROVED	DATE	REVISED DATE
JTL	37933-003		8/97	



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IDEALIZED MASS FLOW DIAGRAM - BIOCHEMICAL PERCHLORATE REDUCTION

FIGURE **5-3**

DRAWN	PROJECT-TASK NUMBER	APPROVED	DATE	REVISED DATE
JTL	37933-003		8/97	

Figure 9-1. Implementation Team